HEART RATE AND BLOOD PRESSURE VARIABILITY UNDER MOON, MARS AND ZERO GRAVITY CONDITIONS DURING PARABOLIC FLIGHTS

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ABSTRACT

Gravity changes during partial-G parabolic flights (0g - 0.16g - 0.38g) lead to changes in modulation of the autonomic nervous system (ANS), studied via the heart rate variability (HRV) and blood pressure variability (BPV). HRV and BPV were assessed via classical time and frequency domain measures. Mean systolic and diastolic blood pressures show both increasing trends towards higher gravity levels. The parasympathetic and sympathetic modulation show both an increasing trend with decreasing gravity, although the modulation is sympathetic predominant during reduced gravity. For the mean heart rate, a non-monotonic relation was found, which can be explained by the increased influence of stress. This study shows that there is a relation between gravity and the modulation of the ANS. With this in mind, countermeasures can be developed to reduce postflight orthostatic intolerance.

1. INTRODUCTION

Postflight orthostatic intolerance is a phenomenon from which many astronauts suffer on their return to Earth. Effective countermeasures are needed to prevent this disorder of the autonomic nervous system (ANS) and the cardiovascular system (CVS). Development of these countermeasures requires the understanding of how the CVS adapts to gravity changes. Parabolic flights are one of the ground-based possibilities to simulate short term (20 seconds) reduced gravity conditions and is used in this study to assess the heart rate variability (HRV) and blood pressure variability (BPV). Due to gravity changes, body fluid hydrostatic pressure gradients arise, leading to a blood and body fluid redistribution. This hemodynamic alternation results in a different parasympathetic and sympathetic interaction [5]. The sympathovagal balance of the ANS can be estimated using classical signal analysis methods in time and frequency domain, calculated in a standardized way [4]. The hypothesis is that there is a monotonic relationship between the HRV and BPV, and the gravity level. In studies from the Laboratory Experimental Cardiology at KU Leuven [1, 2, 5], HRV and BPV are examined during parabolic flights as a function of the hypergravity (1.8g), normogravity (1g) and microgravity phase (0g). However with the present study it is also possible to analyse it at intermediate gravity conditions, those from Moon (0.16g) and Mars (0.38g).

2. METHODS

During the Joint European Partial-G parabolic flight campaign, gravity conditions of Moon (0.16g - 12 parabolas), Mars (0.38g - 12 parabolas) and weightlessness (6 parabolas) were simulated. Five healthy non-smoking male volunteers between 22 and 32 years of age (mean $\pm$ SD: 28 $\pm$ 5 years; stature: 181 $\pm$ 2 cm; mass: 76 $\pm$ 7 kg; BMI: 23 $\pm$ 2), were selected for this study. To eliminate the effects of pharmacological agents that might alter cardiovascular ANS control, neither general medication nor medication for the control of motion sickness were taken before or during the flights. ECG and blood pressure signals were continuously measured in sitting position. Before and after each flight, baseline measurements were collected in a protocol of 10 minutes in supine, standing and sitting position each. A tachogram, containing the RR-intervals as a function of time, is derived from the ECG signal. The blood pressure is preprocessed to obtain the systolic blood pressure (SBP) and diastolic blood pressure (DBP) values as a function of time. From the tachogram and the blood pressure, the influence of the gravity on HRV and BPV is assessed by different indices. The time domain indices are the mean, the standard deviation (std) and the root mean square of the squared differences (rmssd), calculated as described in [4]. The frequency domain indices include: the normalized high frequency (HFnu), the normalized low frequency (LFnu) component and their ratio (LF/HF), calculated as described in [5]. A repeated measures one-way ANOVA is used to test the influence of gravity on the time and frequency domain indices. To fulfil the normality assumption for performing an ANOVA, the data is transformed using a Box-Cox transformation. In order to reduce the effect of excitement on the cardiovascular response, only the last 6 parabolas of each gravity level were used for the statistical analysis.

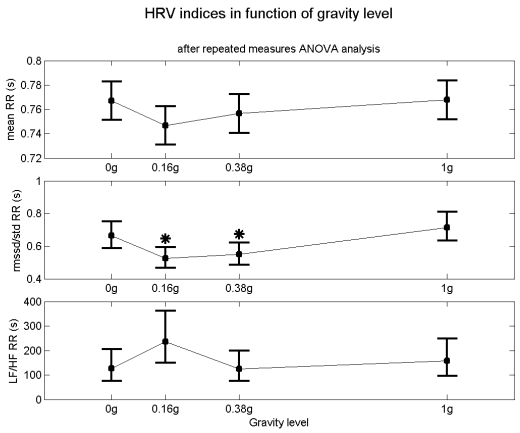


Figure 1. Statistical results from HRV.

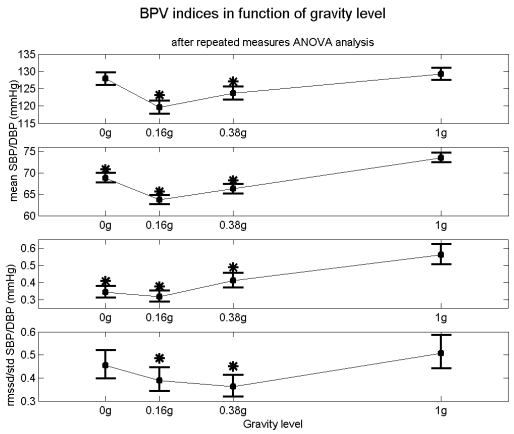


Figure 2. Statistical results from BPV.

3. RESULTS & DISCUSSION

In previous studies, it is proven that the indices are related to the modulation of the ANS [4]. Std corresponds to the total power of the modulation, while rmssd is related with parasympathetic modulation. The ratio rmssd/std reveals the relative importance of the parasympathetic modulation. For the frequency domain measures, the LF component is related to the sympathetic modulation with vagal influences, while the HF component indicates the parasympathetic modulation. The ratio LF/HF reveals therefore the predominance of the sympathovagal balance. Fig. 1 and Fig. 2 show the statistical results for HRV and BPV, respectively, as a function of gravity (0g - 0.16g - 0.38g - 1g). The plots show the mean $\pm$ 2std and the asterix indicates a significant ($p < 0.05$) difference with the baseline normogravity. Although it was hypothesized, a non-monotonic relation of meanRR was found. This shows that there are other factors influencing the heart rate, like the preceding hypergravity phases or the mental stress of the subjects. A slightly lower meanRR, and thus higher heart rate, is found during Moon parabolas and can be explained by the sympathetic predominance, as shown via the LF/HF RR and rmssdRR/stdRR. The Moon parabolas were the first parabolas flown, and thus excitement could have played an important role. Nevertheless, further research is needed to confirm these findings. For the BPV, meanSBP and meanDBP show an increasing trend as a function of gravity, except for the zero gravity. Due to the short duration of the microgravity of these zero gravity parabolas, the influence of the hypergravity plays an crucial role, resulting in a higher meanSBP and meanDBP. This was also discoverd in a study of Liu et al. [2], which found a transition period of about 3-5 seconds in the blood pressure between hypergravity and microgravity. The ratio rmssdSBP/stdSBP and rmssdDBP/stdDBP of the reduced gravity parabolas is significantly lower compared to the normogravity, meaning that there is a higher sympathetic predominance during reduced gravity. This correlation between the sympathovagal imbalance and the occurrence of orthostatic intolerance is found in several studies after performing head-up-tilt tests with subjects with vasovagal syncope [3]. These studies found a significant increase parasympathetic modulation of the mean arterial blood pressure in healthy subjects after a 60° tilt test.

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